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(54) Production method for high strength die cast product

(57) An aluminum-silicon eutectic type casting material containing 7.5 to 12 wt% of silicon and at least one of 1.5 to 4.8 wt% of copper and 0.2 to 0.7 wt% of magnesium is cast by a high speed die casting method. After mold release, the resulting die cast product is subjected, after the surface temperature thereof falls to within the range of 250 to 450°C, to at least one of a water cooling treatment which immerses the die cast product into a water tank and an ageing treatment which retains it at a temperature within the range of 150 to 250°C for a predetermined time.

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a production method for a die cast product which uses an aluminum-silicon eutectic type casting material and for which excellent mechanical strength such as a high tensile strength and a high fatigue strength is required, such as a component for a scroll compressor.

2. Description of the Related Art

Known production methods for high strength die cast products of this kind include a method which casts an aluminum-silicon eutectic casting material by a low speed die casting method at an injection speed of about 0.08 m/sec and then conducts a heat-treatment such as a solution heat-treatment. Because the injection speed of a molten metal is low according to such a low speed die casting method, the entrapped gas quantity is small and a drop in the strength due to the occurrence of cavities (hollow portions) in the die cast product hardly occurs. Nonetheless, the solidification speed of the die cast product is low by this low speed die casting method, and in the case of casting of an aluminum alloy, or the like, solid solution reinforcement components such as copper, magnesium, etc., are selectively precipitated and exist locally inside the aluminum base. For this reason, the die cast product produced by the low speed die casting method is subjected to a solution heat-treatment which retains the die cast product at a temperature of about 500 to about 540°C for several to dozens of hours, in order to improve the mechanical strength. When this solution heat-treatment is effected, the solid solution reinforcement components such as copper and magnesium that are localized inside the aluminum base are uniformly dispersed in the aluminum base, and again undergo solid solution by subsequent water cooling.

However, the low speed die casting method according to the prior art has a low injection speed and moreover, needs a solution heat-treatment of the die cast product for a long time. Therefore, the cycle time for the production of the product inevitably becomes extremely long, thereby inviting the problems that productivity is extremely low and the production cost becomes high. Because the solidification structure becomes coarse in the die cast product produced by the low speed die casting method, variation in the mechanical strength is great. When the product is applied to a scroll compressor component on which a large load acts repeatedly, therefore, a sufficient and constant durability cannot be obtained in some cases.

Because tensile strength, fatigue strength, etc, are required for the scroll component, the Aℓ-Si eutectic type materials (Si content of 7.5 to 12%) have been used, but because the production method is the low speed die casting method, the production time is long and productivity is low, too.

To solve such problems, a high speed die casting method having a high injection speed and high production efficiency, for example, may be applied. Because the injection speed of the molten metal is high and the molten metal is quickly poured into the mold according to the high speed die casting method, however, this method involves the problems that the entrapped gas quantity is great and cavities (hollow portions) are likely to occur in the die cast product. When the die cast product having such a large number of cavities are subjected to the solution heat-treatment, the gas of the cavity portions inflates and, due to this swelling, the product becomes inferior. In other words, the mechanical strength of the die cast product by the high die casting method cannot be improved by solution heat-treatment.

Japanese Unexamined Patent Publication (Kokai) No. 54-153728 teaches to cool the resulting die cast with water after high speed die casting, but the problem of low cuttability exists because this method uses an Aℓ-Si hypereutectic casting material (having a Si content of 17 to 18%).

In view of these problems of the prior art technologies, the present invention aims at providing a die casting method which can produce a high strength die cast product having excellent mechanical properties such as tensile strength, fatigue strength, cuttability, and so forth, within a short time.

SUMMARY OF THE INVENTION

To accomplish the object described above, a production method of a high strength die cast product according to claim 1 of the present invention comprises the steps of injecting an aluminum-silicon eutectic casting material into a mold at an injection speed of at least 1 m/sec in a die casting method, r-leasing the resulting die cast from the mold and then applying at least one of water cooling and an ageing treatment to the die cast product after mold release.

In the production method of a high strength die cast product according to claim 1, the invention set forth in claim 2 applies the ageing treatment to the die cast product after the water cooling treatment.

In the production method of a high strength die cast product according to claim 1, or 2, the invention set forth in claim 3 uses the casting material which contains 7.5 to 12 wt% of silicon and at least one of 1.5 to 4.8 wt% of copper

and 0.2 to 0.7 wt% of magnesium.

In the production method of a high strength die cast product according to claim 3, the invention set forth in claim 4 is characterized in that the surface temperature of the die cast product before water cooling falls to within the range of 250 to 450°C.

In the production method of a high strength die cast product according to claim 4, the invention set forth in claim 5 is characterized in that the water cooling temperature is within the range of 20 to 80°C.

In the production method of a high strength die cast product according to claim 3 or 4, the invention set forth in claim 6 is characterized in that the ageing treatment temperature falls within the range of 150 to 250°C.

In the production method of a high strength die cast product according to claim 6, the invention set forth in claim 7 is characterized in that the ageing treatment temperature is from 0.5 to 8 hours.

In the production method of a high strength die cast product according to claim 8, the invention set forth in claim 7 is characterized in that the ageing treatment time at 180°C is about 4 hours.

In the production method of a high strength die cast product according to any of claims 1 to 5, the invention set forth in claim 9 is characterized in that the die cast product is a component for a scroll compressor.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is an explanatory view showing the mean particle diameter of the solidification structure of a die cast product of each of Example 1 and Comparative Example 1 and its tensile strength ratio;

Fig. 2 is an explanatory view showing a fatigue strength ratio of the die cast product of each of Example 1 and Comparative Example 1; and

Fig. 3 is an explanatory view showing a tensile strength ratio of the die cast product of each of Examples 1 to 3 and Comparative Example 3.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, preferred embodiments of the present invention will be serially explained in detail.

A production method of a high strength die cast product according to the present invention uses an aluminum-silicon eutectic type casting material (hereinafter called merely the "casting material"), casts the casting material by a high speed die casting method, and applies at least one of water cooling and an ageing treatment, after mold release, to the resulting die casting.

Aℓ-Si-Cu, Aℓ-Si-Mg or Aℓ-Si-Cu-Mg system is used as the casting material. In other words, the casting material used in the present invention may contain either one of copper and magnesium or may contain both of them.

Here, silicon has the functions of improving the mechanical strength of the die cast and castability, that is, fluidity of the molten metal. The silicon content is preferably 7.5 to 12 wt% and further preferably, 9 to 12 wt%. When the silicon content is less than 7.5 wt%, the mechanical strength drops gradually and the mechanical strength of the die cast product is likely to be insufficient. In addition, because fluidity of the molten metal drops and its runnability inside the mold becomes insufficient, problems such as sink or shrinkage are likely to develop in the die cast product. When the silicon content exceeds 12 wt%, on the other hand, primary crystal silicon precipitates, so that fluidity of the molten metal drops to invite the drop of castability, and the cuttability of the die cast product drops remarkably. When such a die cast product is applied to a scroll compressor component, breakage of a cutter of the cutting machine occurs frequently and mass-production of the products is difficult.

Copper is one of the solid solution reinforcement components for improving the mechanical strength of the die cast product, and its content is preferably 1.5 to 4.8 wt% and more preferably, 2.5 to 4.8 wt%. When the copper content is less than 1.5 wt% or exceeds 4.8 wt%, the mechanical strength of the die cast product becomes insufficient.

Magnesium is also one of the solid solution reinforcing component for improving the mechanical strength of the die cast product in the same way as copper, and its content is preferably 0.2 to 0.7 wt% and further preferably, 0.3 to 0.7 wt%. When the magnesium content is less than 0.2 wt% or exceeds 0.7 wt%, the mechanical strength of the die cast product becomes insufficient.

After oxide removing treatment and degassing treatment of the molten metal of the casting material are carried out, the molten metal is quickly charged into the mold at a high speed and a high pressure by a high speed die casting method. While the mold is filled with the molten metal, the product portion inside the mold is directly pressurized so as to solidify the die cast product.

The term "high speed die casting method" used in this specification represents a die casting method which injects the molten metal into the mold at an injection speed of not lower than 1 m/sec. Most typically, the injection speed can be at least 2 m/sec. In contrast, a typical injection speed according to the prior art low speed die casting method is not higher than about 0.1 m/sec.

If the die cast product is molded while omitting the oxide removing treatment and the degassing treatment described above, the occurrence of mold cavities varies from die cast product to die cast product and great variance

occurs in the mechanical strength. Therefore, it is in no way preferred to omit the oxide removing treatment and the degassing treatment of the molten metal.

According to the first aspect of the present invention, as soon as mold release of the die cast product is effected, the die cast product is immersed in a water tank for water cooling. The surface temperature of the die cast product subjected to water cooling is preferably within the range of 250 to 450°C and further preferably, within the range of 300 to 400°C. If cooling with water is carried out when the surface temperature of the die cast is less than 250°C, the mechanical strengths of the die cast product, such as its tensile strength and fatigue strength, become insufficient. When cooling with water is carried out under the condition where the surface temperature exceeds 450°C, on the other hand, defects of appearance and internal quality such as local sink and seizure occur, and die cast products having high quality cannot be obtained easily. Incidentally, the water temperature at the time of water cooling hardly affects the mechanical properties of the die cast product, and is set to the range of 40 to 60°C in this embodiment.

According to the second aspect of the present invention, the die cast product after water cooling or mold release is left standing for ageing treatment for a predetermined time under a heated state. The temperature of this ageing treatment is preferably within the range of 150 to 250°C, and further preferably within the range of 170 to 210°C. If the ageing treatment is carried out at a treating temperature less than 150°C or exceeding 250°C, the hardness of the die cast product cannot be improved sufficiently, and its mechanical strength is likely to be insufficient. The ageing treatment time is generally from 0.5 to 8 hours, and in the case of the ageing treatment at 180°C, for example, it is sufficient that the treatment time be about 4 hours.

According to these aspects of the present invention, the following effects can be obtained.

(1) Since casting is carried out by the high speed die casting method using the aluminum-silicon eutectic type casting material, the pouring time of the molten metal into the mold becomes shorter than in the conventional low speed die casting method. Therefore, the casting time can be reduced and the production cycle time of the die cast product can be shortened.

(2) Since casting is carried out by the high speed die casting method, the solidification speed of the die cast product is high, and the solid solution reinforcement components such as copper and magnesium are uniform solid solutions inside the aluminum base. In consequence, hardening can be conducted by water cooling the die cast product after mold release, and a sufficient mechanical strength can be obtained by subsequently carrying out only the ageing treatment for a short time. Therefore, the solid solution treatment for a long time need not be carried out, and the cycle time of the production can be remarkably reduced.

(3) Since the solidification speed is high, the solidified structure becomes compact and orientation of the crystal can be reduced, so that the die cast product having a high fatigue strength can be obtained. Such a die cast product is suitable for a scroll compressor component to which a large load is repeatedly applied. Therefore, the component is not easily broken and the durability of the scroll compressor can be improved.

(4) Since the surface temperature of the die cast product before water cooling is adjusted to the temperature within the range of 250 to 450°C, the mechanical strength of the die cast product can be improved.

(5) Since the ageing treatment is carried out at the temperature within the range of 150 to 250°C, the mechanical strength of the die cast product can be improved. Moreover, this heat-treatment does not require a high temperature at which the die cast product is re-molten, as has been necessary in the conventional solid solution treatment, and this is advantageous from the aspect of energy, too.

(6) The oxide removing treatment and the degassing treatment of the molten metal are carried out and moreover, the product portion inside the mold after injection is directly pressurized. Therefore, the products having small variance of quality can be produced.

Various properties of products produced by the following production methods (A) to (D) are tabulated below.

(A) A method which casts the aluminum-silicon eutectic material by the low speed die casting method and heat-treats the resulting casting according to the prior art.

(B) A method which casts the aluminum-silicon hypereutectic material by the high speed die casting method and cools the resulting casting with water, as disclosed in Japanese Unexamined Patent Publication (Kokai) No. 54-153728.

(C) A method in which the hypereutectic material in the method (B) is replaced by a eutectic material.

(D) A method according to a preferred embodiment of the present invention wherein the contents of Cu and Mg, the temperature before water cooling, the water cooling temperature, the ageing temperature and the ageing time are specifically stipulated in the method (C).

production method	(A)	(B)	(C)	(D)
tensile strength	○	○	△	○
fatigue strength	○	○	△	○
cuttability	○	X	○	○
wear characteristics	△	○	△	△
process time	X	○	○	○

○: excellent
△: fair
X: inferior

EXAMPLES

Next, the present invention will be explained further concretely with reference to Examples and Comparative Examples thereof, but the invention is in no way limited thereto.

Example 1

A molten metal of an aluminum-silicon eutectic type casting material containing 10.5 wt% of silicon, 4.2 wt% of copper and 0.5 wt% of magnesium was first subjected to an oxide removing treatment and a degassing treatment. This molten metal was injected into a mold for a scroll compressor component at an injection speed of 2.0 m/s by using a 650-ton horizontal die casting machine. A casting pressure of 750 kgf/cm^2 was allowed to act on the mold so that the product portion could be directly pressurized. This pressurized state was kept for a predetermined time, and the molded die cast product was released from the mold and withdrawn. The die cast product after mold release was immediately immersed into a water tank, was cooled with water and was retained at 180°C for 4 hours for an ageing treatment.

Comparative Example 1

Casting was carried out in the same way as in Example 1 with the exception that a low speed casting method was employed and the molten metal was injected into the mold at an injection speed of 0.08 m/s. The other conditions were the same as those in Example 1.

Fig. 1 shows the mean particle size of the solidified structure of the die cast product of each of Example 1 and Comparative Example 1, and a tensile strength ratio of the die cast product of Example 1 relative to that of the die cast product of Comparative Example 1. As shown in Fig. 1, the mean particle size of the solidified structure was about 2 μm in the die cast product of Example 1, whereas it was about 30 μm in the die cast product of Comparative Example 1. As to the tensile strength, the die cast product of Example 1 exhibited a value which was by about 50% greater than that of the die cast product of Comparative Example 1. In other words, the die cast product of Example 1 casted by the high speed die casting method had a compact solidified structure and a high tensile strength.

Comparative Example 2

The molten metal of a casting material having the same composition as that of the material of Example 1 was injected into the mold at an injection speed of 0.08 m/s, to form a die cast product by a low speed die casting method. Solid solution treatment and ageing treatment were carried out by holding the die cast product at 520°C for 8 hours.

Fig. 2 shows the ratio of the lower limit value of variance of the fatigue strength of the die cast product of Example 1 to that of Comparative Example 2 when each die cast product was actually fitted to a scroll compressor and the compression operation was carried out 10^7 times. As shown in Fig. 2, the die cast product of Example 1 had a tensile strength by about 50% higher than that of the die cast product of Comparative Example 2. The fatigue strength of the die cast product of Example 1 casted by the high speed die casting method exhibited its variance at a high level, and the product was suitable for a scroll compressor component to which a large load was repeatedly applied.

Example 2

Example 2 represents the case where water cooling was omitted in Example 1, and the die cast product after mold release was annealed and was then subjected to ageing treatment.

Example 3

Example 3 represents the case where the ageing treatment was omitted in Example 1.

Comparative example 3

Comparative Example 3 represents the case where both water cooling and ageing treatment were omitted in Example 1, and the die cast product after mold release was annealed.

Fig. 3 shows the tensile strength ratio of the die cast product of each of Examples 1 to 3 to that of the die cast product of Comparative Example 3. As shown in Fig. 3, the tensile strength value of the die cast products of Examples 2 and 3, wherein water cooling or the ageing treatment was carried out, was by about 20% greater than the tensile strength value of Comparative Example 3 in which they were not carried out. In other words, the improvement in the tensile strength could be observed in Examples 2 and 3. In contrast, in the die cast product of Example 1 wherein both of water cooling and ageing treatment were carried out, the tensile strength was about 50% greater than that of the die cast product of Comparative Example 3, and the tensile strength could be improved greatly.

Example 4 and Comparative Examples 4 and 5

In these Examples, the contents of copper and magnesium as the solid solution reinforcement components of the casting material of Example 1 were changed to the compositions tabulated in the following Table 1.

Table 1

	water-cooling and ageing	main composition (wt%)			tensile strength ratio to Comp. Example 3
		Si	Cu	Mg	
Example 1	YES	10.5	4.2	0.5	1.5
4	YES	10.6	3.0	0.5	1.3
5	YES	10.5	4.1	0.3	1.2
Comp. Example 3	NO	10.5	4.2	0.5	1.0
4	YES	10.5	5.5	0.5	0.8
5	YES	10.6	4.2	0.8	0.9

Table 1 shows the tensile strength ratio of the die cast product of each of Examples 1, 4 and 5 and Comparative Examples 3 to 5. As shown in Table 1, the tensile strength was greater, by 30%, even in the die cast product of Example 4 using the casting material having the copper content of 3.0 wt% than the tensile strength of Comparative Example 3, and the improvement in the tensile strength could be observed. In contrast, in the die cast product of Comparative Example 4 which used the casting material having the copper content of 5.5 wt%, the drop of the tensile strength was observed in comparison with the die cast product of Comparative Example 3.

In the die cast product of Example 5 using the casting material having a magnesium content of 0.3 wt%, too, the tensile strength was 20% greater than that of the die cast product of Comparative Example 3, and the improvement in the tensile strength could be thus observed. In contrast, in the die cast product of Comparative Example 5 using the casting material having the magnesium content of 0.8 wt%, the drop of the tensile strength could be observed in comparison with the die cast product of Comparative Example 3.

By the way, the present invention can be carried out by modifying the embodiments thereof in the following way.

(1) In the casting materials of the foregoing embodiments, small amounts of a component for preventing softening of the die cast product at a high temperature (such as nickel and manganese), a component for fining the crystal grain (such as titanium and chromium), a component for improving mold releasability and restricting erosion of the

mold (such as iron) and other components for improving the properties of the die cast product may be added (in amounts less than 0.5 wt%).

Next, the technical concept grasped by the foregoing embodiments will be described.

(1) A production method of a high strength die cast product according to any of claims 1 through 5, comprising subjecting a molten metal to an oxide removing treatment and a degassing treatment, injecting the molten metal into a mold, and directly pressurizing a product portion inside the mold.

When the invention is constituted as described above, products having less variance of quality can be produced.

As described above in detail, the present invention provides the following excellent effects.

According to the invention described in claims 1 and 2, casting is carried out by the high speed die casting method using the aluminum-silicon eutectic casting material. Therefore, the charging time of the molten metal into the mold becomes shorter than in the conventional low speed die casting method. As a result, the casting time as well as the production cycle time of the die cast products can be reduced.

Since casting is carried out by the high speed die casting method, the solidification speed of the die cast product is high and the solid solution reinforcement components such as copper and magnesium undergo uniform solid solution in the aluminum base. Accordingly, the die cast product after mold release can be cooled with water and hardened, and because the ageing treatment is carried out for only a short time, a sufficient mechanical strength can be obtained. In other words, the solid solution treatment for a long time need not be conducted, and the cycle time of the production can be shortened.

According to the invention as set forth in claim 3, the casting material contains 7.5 to 12 wt% of silicon and at least one of 1.5 to 4.8 wt% of copper and 0.2 to 0.7 wt% of magnesium. Therefore, the characteristic properties of each element can be fully exploited.

According to the invention as set forth in claim 4, the surface temperature of the die cast product before water cooling is adjusted to the temperature within the range of 250 to 450°C. Consequently, the mechanical strength of the die cast product can be improved.

According to the invention as set forth in claim 5, the ageing treatment is carried out at a temperature within the range of 150 to 250°C. In consequence, the mechanical strength of the die cast product can be improved. Further, because the die cast product can be treated at a lower temperature than the solid solution heat-treatment, the present invention is advantageous from the aspect of energy.

According to the invention as set forth in claim 6, because the solidification speed is high as described above, the solidification structure can be made compact and directivity of the crystal can be eliminated, so that a die cast product having an excellent fatigue strength can be obtained. Such a die cast product is suitable for a scroll compressor component on which a large load repeatedly acts. Therefore, the component is not easily broken and the durability of the scroll compressor can be improved.

Claims

1. A production method for a high strength die cast product comprising the steps of:

   injecting an aluminum-silicon eutectic type casting material into a mold at an injection speed of at least 1 m/sec by a die casting method;
   releasing the resulting die cast product from said mold; and
   applying at least one of cooling with water and an ageing treatment to said die cast product so released from said mold.

2. A production method for a high strength die cast product according to claim 1, wherein said ageing treatment is applied to said die cast product after said water cooling.

3. A production method for a high strength die cast product according to claim 1, wherein said casting material contains 7.5 to 12 wt% of silicon and at least one of 1.5 to 4.8 wt% of copper and 0.2 to 0.7 wt% of magnesium.

4. A production method for a high strength die cast product according to claim 3, wherein said die cast product before said water cooling has a surface temperature within a range of 250 to 450°C.

5. A production method for a high strength die cast product according to claim 4, wherein the water cooling temperature is within a range of 20 to 80°C.

6. A production method for a high strength die cast product according to claim 3, wherein the temperature of said ageing treatment is within a range of 150 to 250°C.

7. A production method for a high strength die cast product according to claim 6, wherein the time period of said ageing treatment is 0.5 to 8 hours.

8. A production method for a high strength die cast product according to claim 7, wherein the time of said ageing treatment is about 4 hours at 180°C.

9. A production method for a high strength die cast product according to claim 1, wherein said die cast product is a component for a scroll compressor.

Fig.1

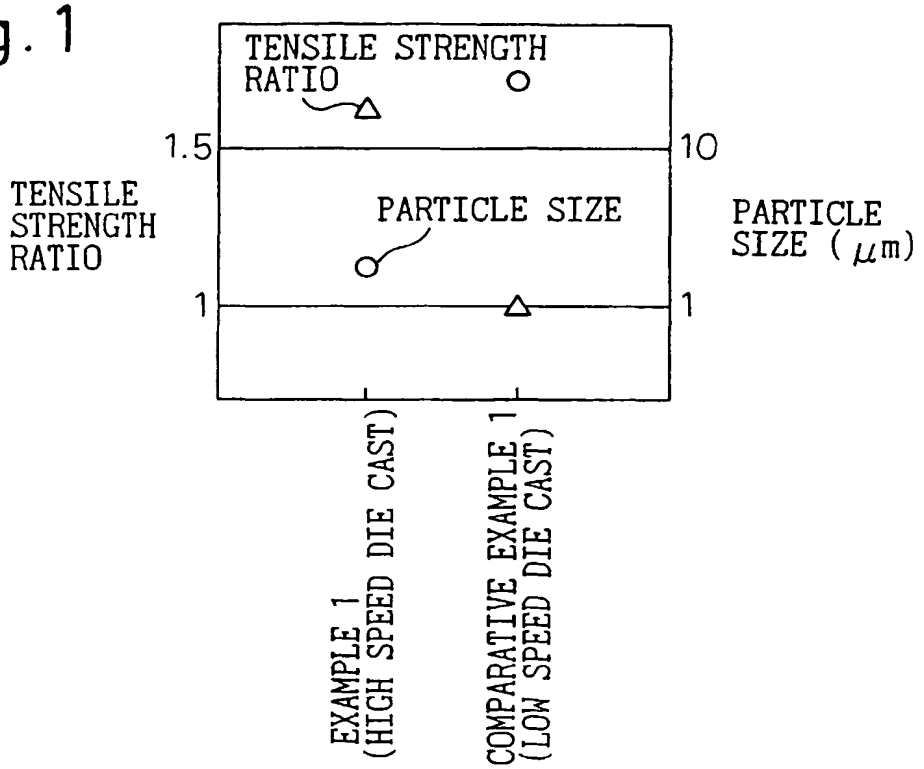


Fig.2

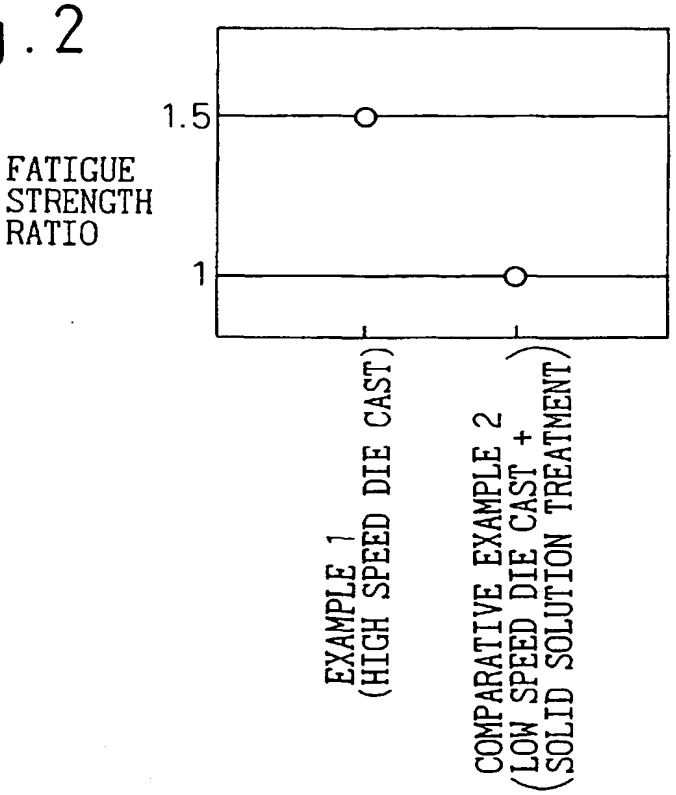
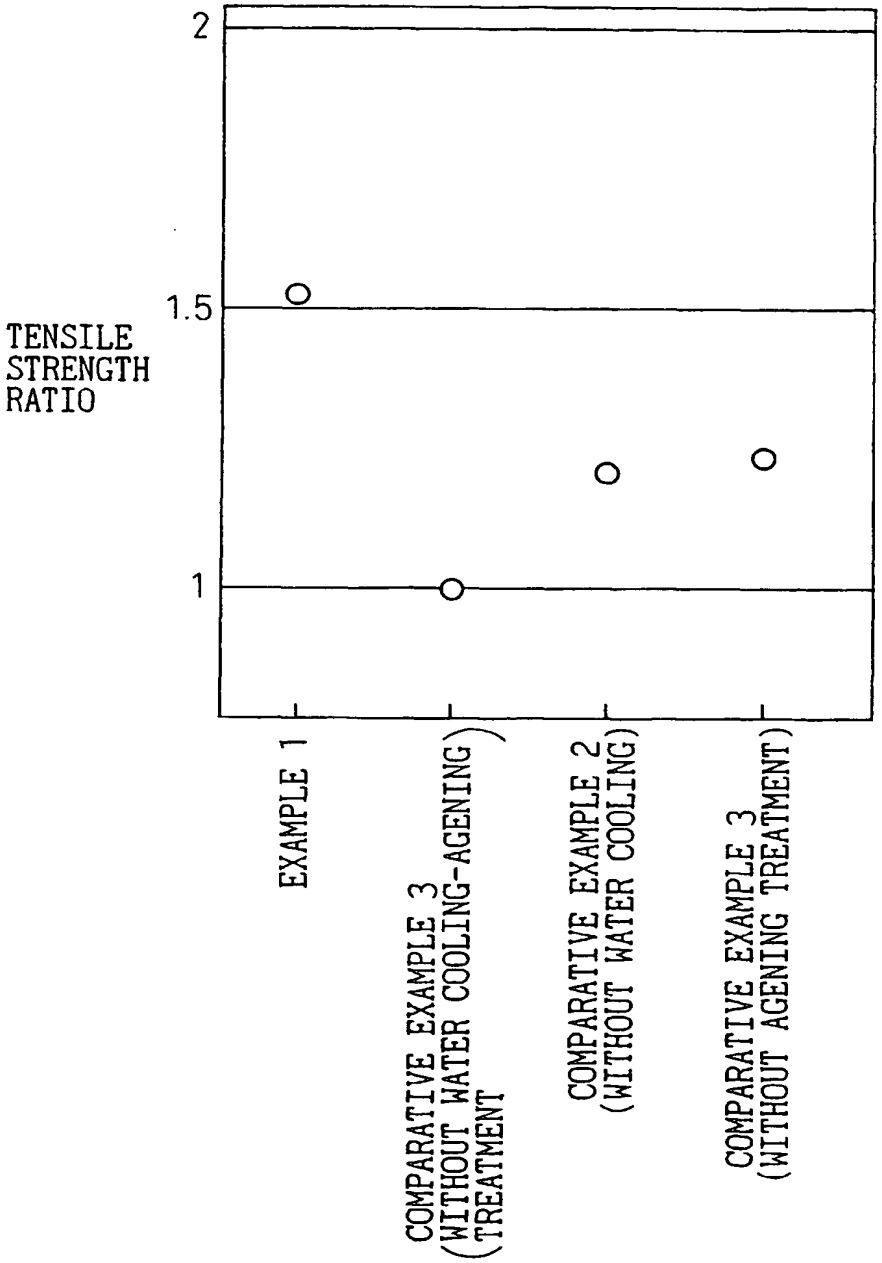


Fig. 3



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EUROPEAN SEARCH REPORT

Application Number
EP 97 10 4527

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
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A	PATENT ABSTRACTS OF JAPAN vol. 011, no. 347 (M-641), 13 November 1987 & JP 62 126283 A (MITSUBISHI HEAVY IND LTD), 8 June 1987, * abstract *	1-3,9	TECHNICAL FIELDS SEARCHED (Int.Cl.6) C22C B22D
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	16 June 1997	Gregg, N

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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EPO FORM 1503 03.82 (P04C01)

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DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	DE 38 17 350 A (SUMITOMO ELECTRIC INDUSTRIES) 22 December 1988 -----		

TECHNICAL FIELDS SEARCHED (Int.Cl.6)

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